AUTOMATIC GENERATION OF FRAMES FOR DIGITAL IMAGES

Field of the Invention

5   The present invention relates generally to digital image processing, and pertains

more particularly to processing a digital image so as to automatically generate a visually

pleasing frame for the image.

Background of the Invention

10   In recent times, digital cameras capable of taking a digital photograph of a scene

and recording a corresponding digital image file have come into widespread usage. The

quality of such cameras has recently improved to the point where they are capable of

15   capturing digital images with sufficiently high resolution and colorfulness that good quality

digital photographic prints up to an 8 inch by 10 inch size, or even larger, can now be

made when the digital image file is printed on a photographic-quality computer printer. In

addition to digital cameras, scanners or multifunction printers can also generate digital

image files of similar or better resolution by optically scanning a traditional photographic

20   print.

Photographic prints are frequently intended for mounting in a picture frame.

Typical plastic or wooden frames serve to provide a border around the print. The border

can range from narrow to wide, and from simple to ornate. Frames typically also provide

a transparent covering, typically glass or clear plastic, over the print. Before (or

- 2 -

sometimes instead of) framing, some prints are matted, typically with one or more colored cardboard mats.

Picture frames of a given size come in a range of prices, with higher quality or more ornate frames typically being more expensive. Because of the border provided by

5   the mat, a matted print needs a larger size frame than would be needed for the unmatted print. The mat boards themselves are an added cost. In addition, while pre-cut mat boards are available for standard-size prints (eg. 5x7, 8x10, 11x14, etc.), mat boards for either odd-size frames or odd-size prints must typically be cut by the user.

Since matted and framed prints are typically intended to be wall-mounted and

10   displayed, for example, in a home or office, it is important that the combination of frame, mat, and print be a visually pleasing one. It is thus necessary for a person to choose a frame and mat having the proper colors to achieve such a visually pleasing result.

The cost and time involved with shopping for the proper frame, mat board, or both can be considerable. Also, determining which color frame and mat(s) will provide an

15   aesthetically pleasing result can be confusing and/or time-consuming. In some cases, the ideal color or pattern may not be available at all.

Some computer graphics programs provide a predefined set of "digital frames" that can be combined with digital images prior to printing. Typically a variety of border styles and colors are provided for the user to select from. While such a program may

20   reduce shopping time and cost associated with framing, it is still left up to the user to determine what color and style of border will provide a visually pleasing result.

- 3 -

Accordingly, it would be highly desirable to have a new and improved image processing

apparatus and method that frames a digital image in a visually pleasing manner without

undue effort on the part of the user.

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Summary of the Invention

In a preferred embodiment, the present invention provides a method that

automatically generates a visually attractive frame around a digital image based on

particular characteristics of the image. By printing the combined frame and image on a

10 hardcopy output device such as a printer, a framed image is conveniently and

inexpensively realized. The method analyzes at least a portion of the data set representing

the rows and columns of pixels of the digital image so as to identify one or more image

characteristics of the digital image. Based on the image characteristics, one or more

attributes of a visually attractive frame are automatically determined, and a second data set

15 is generated for the framed image. The pixels of the second data set define a

representation of the unframed digital image surrounded by a frame having the frame

attributes.

Brief Description of the Drawings

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The above-mentioned features of the present invention and the manner of attaining

them, and the invention itself, will be best understood by reference to the following

detailed description of the preferred embodiment of the invention, taken in conjunction

with the accompanying drawings, wherein:

FIG. 1 is a block diagram of a novel image processing apparatus for automatically

framing a digital image according to the present invention;

5   FIG. 2 is a schematic data flow representation of the automatic framing of a digital

image as performed by the image processing apparatus of FIG. 1;

FIG. 3 is a two-dimensional image space representation of an unframed image

framable by the image processing apparatus of FIG. 1;

FIG. 4 is a three-dimensional color space representation of an unframed image

10   framable by the image processing apparatus of FIG. 1;

FIG. 5 is a top-level flowchart of a novel automatic frame generation method

usable with the image processing apparatus of FIG. 1;

FIGS. 6 and 7 are lower-level flowcharts of different portions of the automatic

frame generation method of FIG. 5; and

15   FIG. 8 is a three-dimensional color space representation illustrating a variety of

color schemes used to determine a visually attractive frame for the digital image according

to the method of FIG. 5.

Description of the Preferred Embodiment

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Referring now to the drawings, there is illustrated an image processing apparatus

constructed in accordance with the present invention which automatically generates a

visually attractive printed frame or border around a print of a user-selected digital image, in accordance with a novel image processing method of the invention. Such an apparatus analyzes the contents of the digital image and automatically determines a color pattern for the frame or border that will provide a visually pleasing effect. The apparatus thus can

5   reduce the confusion and time expended by a person to manually mat and frame a print of the digital image. Incorporating the frame or border into the print of the digital image may also allow a less-expensive frame to be used to physically mount the print.

As best understood with reference to FIGS. 1 and 2, a preferred embodiment of the image processing apparatus 10 includes an image analyzer 20 that is communicatively

10   coupled to a framed image generator 40. In operation, the image analyzer 20 processes a data set representing an unframed digital image 22 so as to determine one or more frame attributes of a frame 26 that is visually attractive when combined with the unframed digital image 22. The frame attributes are provided to the framed image generator 40, which in turn processes the data set for the unframed digital image 22 in order to generate a new

15   data set for the framed digital image 24. The new data set for the framed digital image 24 includes data representing the unframed digital image 22 surrounded by a frame 26 having the frame attributes. The image analyzer 10 will be subsequently considered in further detail, after a discussion of a novel method of image processing according to the present invention that is usable with the image processing apparatus 10.

20   Before discussing the novel image processing method in further detail, however, it is beneficial to briefly discuss the data sets that are used to represent digital images with

reference to FIG. 3. As is known to those skilled in the art, the digital data representing

an image 22 typically is stored as a set of individual image pixels. These pixels may be

logically mapped to in rows (such as exemplary rows 7) and columns (such as exemplary

columns 8) of a two-dimensional image space 6 to form the image 22. Each image pixel

5   represents the color and intensity of a small rectangular area 19 of the image 22. Typically

each row and column has a pixel resolution of at least 75 to 600 or more pixels per inch.

Image pixel data may be stored in a variety of different formats. A preferred format is

RGB. A pixel in RGB format contains three parameters: one each for red, green, and blue

colored information. The value of each of these parameters indicates the intensity of the

10   corresponding color at that pixel. The various possible combinations of the red, green,

and blue parameters allow different pixels to represent a wide range of colors and

intensities. When the color and intensity of each pixel is displayed or printed in this two-

dimensional image space, the image 22 is depicted.

       Alternatively, and with reference to FIG. 4, the image data pixels may also be

15   logically mapped to a number of alternative three-dimensional color spaces known to

those skilled in the art, such as HSL color space 50. HSL color space 8 may be

represented as a cone having a central axis 52 representing lightness (L), a radial axis 54

extending out from the central axis 52 representing saturation (S), and an angular

component 56 representing the hue (H). The particular shade of color of a pixel, such as

20   pixels 51, is represented as a position on a plane of the cone orthogonal to the lightness

axis 52, while the lightness or darkness of a pixel is represented by the location on the

lightness axis 52 of the plane. As will be discussed subsequently in further detail,

arranging the pixels of the unframed image 22 in a three-dimensional color space is

beneficial for automatically generating a visually pleasing frame for the image 22. While

the HSL color space is depicted here for simplicity of understanding, the HSL color space

5   is logarithmic with respect to the characteristics of human visual perception, and therefore

it should be understood that the preferred color space for the present invention is CIE

L*a*b* space which has a linear relationship to human visual perception. Further details

about these color spaces, and about the conversion of RGB data to and from these spaces,

is well understood by those skilled in the art. See, e.g., "Frequently Asked Questions

10   about Color" by Charles A. Poynton, and "Color Space Conversions" by Adrian Ford and

Alan Roberts, both of which are presently available on the world wide web at

http://Home.InfoRamp.Net/~poynton/ColorFAQ.html.

Bearing in mind the preceding discussion of image data pixels, image space, and

color space, the present invention, as best understood with reference to FIGS. 2 and 5,

15   may also be implemented as a method 100 for automatically generating a framed digital

image from the data for an unframed digital image. The method begins at 102 by

predefining a number of image categories 32, as will be discussed subsequently in further

detail, that specify a default mapping relationship between the image characteristics of

images 22 to be framed, and the attributes of a visually attractive frame 26 for those

20   images. At 104, and as will also be described subsequently in greater detail, the data set

for an unframed image 22 is analyzed to identify one or more image characteristics. At

- 8 -

106, and as will additionally be described subsequently in greater detail, the method

determines, from the image characteristics, certain frame attributes of a visually attractive

frame for the image. At 108, a data set for a framed image 24 is generated. The data set

includes data for a representation 22' of the unframed image 22, and a frame 26 having the

5   frame attributes surrounding the unframed image 22. The unframed image 22 may, as will

be discussed subsequently, be scaled in size or otherwise adjusted to form the

representation 22' that is included in the framed image 26. At 110, it is determined

whether or not the data set for the framed image 24 should be modified; usually this

includes providing a visual preview of the framed image 26 to a user. If the user wishes to

10   modify the framed image ("Yes" branch of 110), he or she can modify the mapping

relationship at 112 as will be described subsequently, and the method branches to 106 to

redetermine the frame attributes. If the user does not wish to modify the framed image

("No" branch of 110), then at 114 the data set for the framed image 24 is sent to an

imaging device 14a-14e for display or printing, or to a storage device such as a disk drive

15   for later access and use.

Considering now in further detail the analyzing 104 of the data set for the

unframed image 22, and with reference to FIGS. 2, 3, 4, and 6, the analysis is dependent

on whether the data set is analyzed in image space or in color space. If it is to be analyzed

in image space 6 ("Image Space" branch of 116), then at 118 the pixels are mapped to the

20   rows 7 and columns 8 of the image space 6. At 120, at least one spatial region of pixels,

such as those mapped to regions 9a-9f, of the image space 6 are identified as image

components. The image components may be located in fixed positions within the image

space 6. Some embodiments may use a single image component, which may be, for

example, the entire image space 6, a larger central portion 9f, or a smaller central portion

9c. Other embodiments may have a number of image components such as, for example,

5   the five image components 9a-9e. The image components, rather than being in fixed

positions in image space, may be dynamically determined based on the image being

analyzed. For example, for the landscape scene depicted in FIG. 3, a region 9e

encompassing the leaves of the tree, a region 9a encompassing the sky, and a region 9d

encompassing the house may be used. At 122, each image component is characterized

10   independently to determine component characteristics such as color, and lightness. These

characteristics may be calculated by averaging, by weighted-average techniques such as

center-weighting, or the like.

If the data set is to be analyzed in a color space, such as HSL color space 50, then

at 124 the pixels are mapped to their appropriate positions within the color space 50. The

15   appropriate position is determined by transforming the RGB parameters for each pixel into

the corresponding HSL (or other color space) coordinates, according to calculations

known to those skilled in the art. At 126, at least one region of pixels, such as those

mapped to regions 58a-58f, of the image space 50 are identified as image components.

The preferred method of identifying such regions is via the mathematical technique known

20   as principal component analysis. As is known to those skilled in the art, principal

component analysis provides the ability to find clusters of data that are embedded in

subspaces of high-dimensional data. See, e.g., M. Kirby, F. Weisser, and G. Dangelmayr, "A model problem in the representation of digital image sequences", Pattern Recognition, 26(1):63-73, 1993; see also M. Turk and A. Pentland, "Eigenfaces for recognition", J. of Cognitive Neurosci., 3(1), 1991. Once the appropriate set of image components has been

5   identified, at 128 each image component is characterized independently to determine component characteristics such as color, lightness, pixel concentration, volume, and density.

It is instructive to define these terms, with reference to FIG. 4, before continuing with the analyzing 104 of the data set. "Color" refers to the position defined by the hue

10   56 and saturation 54 parameters of the component, such as any of components 58a-58f. Since these components occupy a volume, rather than a single point, in the color space, color may be determined by averaging (or weighted-averaging) the hue and saturation of each pixel 51 in the component, determining a central point of the volume, or the like. "Lightness" refers to the position of the component on the lightness axis 52, again

15   determined by averaging, weighted-averaging, or the like. "Pixel concentration" is the percentage of the total image pixels 51 in the data set for the image 22 that are located within the volume of the component. "Volume" is the span of color space 50 that is encompassed by the component. "Density" is the number of pixels 51 per unit volume of the component. It should be note that this list of component characteristics is not

20   exhaustive, and that other characteristics may be chosen to describe the component in accordance with the present invention.

- 11 -

Continuing now with the analyzing 104 of the data set, at 130 the entire image 22

is collectively characterized, based on the individual characteristics of each image

component 58a-f, in order to determine a set of overall image characteristics. These

characteristics describes the overall color attributes of the image. The overall image

5   characteristics, as will be discussed subsequently in further detail, are used to categorize

the image and determine attributes of a visually attractive frame for the image. The image

characteristics preferably include, but are not limited to, color temperature, contrast ratio,

colorfulness, and color strength. "Color temperature" refers to the visual perception of

color in which reds and yellows are perceived as "warm" colors and blues and greens as

10   "cool" colors. "Contrast ratio" describes the range of lightness values present in the

components of the image. A low contrast image has components which fall in a narrow

range of lightness values, while a high contrast image has components which fall in a wide

range of lightness values. "Colorfulness" describes how much of its hue a particular

region appears to exhibit. "Color strength" is a photographic term which incorporates

15   combined attributes of both colorfulness and lightness.

Before considering the determining 106 of frame attributes based on the image

characteristics, it is useful to consider by way of example, and with reference to Table I,

how the image characteristics can be indicative of the subject matter of the image 22. An

image 22 with components that primarily have warm colored hues (for example, hues from

20   red to yellow and including orange and burgundy) may be indicative of a portrait of a

person. An image 22 with components that primarily have cool colored hues (for example,

- 12 -

hues from green to violet and including blue, cyan, and grey) may be indicative of a

landscape scene. An image 22 whose white colors are shaded toward warm colors may

indicate an indoor photograph taken under incandescent lighting, while an image 22 whose

white colors are shaded toward cool colors may indicate an outdoor photo. Image

5   categorizations of this sort are useful in determining the attributes of a frame 26 that will

be visually attractive when combined with the image 22. As previously described, the

method 100 includes predefining 102 the image categories 32, and specifying framing

scheme rules for each image category that will be used by the method 100 to determine

frame attributes. In a preferred embodiment, the image categories 32 are implemented as

10   mapping tables in software or firmware. Each image category may specify the rules for

determining different aspects of the framing scheme, preferably including a color scheme,

intensity, texture, and dimensionality of a border or frame 26 that will be visually attractive

when combined with the image 22. The list of image categories in Table I is merely

illustrative, and neither comprehensive nor limiting; a wide variety of image categories can

15   be defined and used to determine frame attributes according to the present invention. For

example, additional image categories such as floral, city, industrial, and nighttime scenes

could be defined, each with its own set of framing scheme rules.

Image Characteristics	Image Category	Framing Scheme Rules			
		Color Scheme	Intensity	Texture	Dimension'ty
Primarily warm hues	Portrait	• If contrast=normal, color scheme = complementary • If contrast=low, color scheme = dark • If contrast=high, color scheme = light	Normal	Flat	2D
Primarily cool hues	Landscape	• If color=green or blue, color scheme = similar • If color=brown, color scheme = contrasting	Strong	Flat	2D
All other combinations	Default	• If contrast=normal, color scheme = complementary • If contrast=low, color scheme = white • If contrast=high, color scheme = black	Muted	Flat	2D

Table I – Predefined Image Categories

5   Considering now in further detail the determining 106 of frame attributes of a

visually attractive frame 26 for the image 22, and with reference to Table I and FIGS. 2, 4,

and 7, the frame attributes that will be determined preferentially include the number of

individual borders in the frame 26 and, for each border, the border width, border color,

border texture pattern, and border shading pattern. The determining 106 of frame

10   attributes begins at 132 by examining the overall image characteristics to determine

whether the image characteristics match one of the predefined image categories. If such a

matching image category is found ("Yes" branch of 134), then at 136 the framing scheme

associated with that image category is selected for use. If no matching image category is

found ("No" branch of 134), then at 138 the framing scheme for the default image

category is selected for use.

At 140, the number of borders incorporated in the frame 26, and the width of each

border, are determined. The number and width of the borders are preferably determined

5   based on the dimensions of the unframed image representation 22' (x_i and y_i) and the

framed image 24 (x_f and y_f).

If the dimensions of the unframed representation 22' are more than about 60% of

the dimensions of the framed image 24, then preferably the frame 26 will include only a

single border region. Conversely, if the dimensions of the unframed representation 22' are

10   less than about 30% of the dimensions of the framed image 24, then two or more border

regions will preferably be used. As indicated in Table I, the border regions are 2-

dimensional by default for all image categories.

At 142, a visually pleasing color for each border is determined. This visually

pleasing color is determined based on the color scheme and intensity framing scheme rules

15   for that border. A large number of color schemes may be defined and incorporated into

the framing scheme rules. As best understood with reference to Table II, in some of these

color schemes, the border color is independent of the colors contained in the image. For

example, a "cultural" color scheme would utilize color attributes that are more pleasing to

viewers from a particular cultural background, and a "national" color scheme would use

20   certain color combinations that have specific meanings in a particular country. If the

image characteristics are indicative of an image concerning the United States, for example,

red, white, and blue hues might be used in borders. Similarly, a "gender" color scheme might produce a border with pink hues if the image characteristics are indicative of a girl, and blue hues if indicative of a boy. An Asian color scheme would preferably use more reds and more vivid colors than would a European color scheme.

5   For others of these color schemes, and with reference to FIG. 8 and Table II, the border color is determined relative to a dominant color contained in the image. The dominant color is preferably that of the principal image component. To illustrate by way of example, the dominant color in an image 22 is indicated by a point 80. A "same" color scheme would use a hue 81 that is the same as the hue of the dominant color 80 in the

10   color space 50. A "similar" color scheme would use a hue 82 that is adjacent in color space 50 to the dominant color 80. A "complementary" color scheme would use a hue 83 that is opposite in color space 50 to the hue of the dominant color 80. A "contrasting" color scheme would use a hue 84 that is adjacent in color space 50 to the opposite hue of the dominant color 80. A "dark" color scheme would use the same hue as the dominant

15   color 80 but a lightness 85 that is less than the lightness of the dominant color 80. A "light" color scheme would use the same hue as the dominant color 80 but a lightness 86 that is more than the lightness of the dominant color 80. A "progressive" color scheme would use the same hue as the dominant color 80 but a lightness and saturation 87 that is less than the lightness and saturation of the dominant color 80. The particular color point

20   on the appropriate line segment 81-87 is determined by the intensity parameter of the framing scheme. The intensity parameter typically provides a choice of a few points along

the line segment, which may be denoted as "strong", "normal", and "muted". Where

multiple borders are used, the colors of each of the different borders preferably have

similar hues.

Absolute Color Schemes (Independent of Dominant Color)	Border Color examples
White	White
Black	Black
Cultural	More vivid colors and more reds if image = Asian scene
National	Red, white, & blue hues if image=United States scene
Gender	Pink hue if image=female, blue hue if image=male
Relative Color Schemes (Dependent upon Dominant Color)	Border Color examples
Same	Same hue as dominant color
Similar	Hue adjacent in color space to dominant color
Progressive	Same hue as dominant color but different saturation and/or lightness
Complementary	Opposite hue to dominant color
Contrasting	Adjacent hue to opposite hue of dominant color
Achromatic	Remove color (saturation=0), same lightness level as dominant color
Vivid	Fully saturate the hue
Light	Same hue with increased lightness
Dark	Same hue with reduced lightness

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Table II – Color Scheme Implementations

At 144, a texture pattern for each border is determined, based on the border

texture for that border. Preferably the border texture can be either flat or patterned. All

10   pixels of a border with a flat texture (except for shaded areas, as discussed below) have

the same color. In a border with a patterned texture, a pattern is first determined and then

replicated to form the border. The pattern is preferably much smaller than the width of the

border. The pixels of a pattern preferably use related colors, such as similar or

progressive hues, and the pixels on the edges of the pattern are chosen so as to form

visually matching interfaces when the pattern is replicated to form the border.

At 146, at least one shading color for each border is determined, based on the

5 dimensionality for that border. Preferably the options for dimensionality are two-

dimensional or three-dimensional. Three-dimensional is typically used for only the

outermost border, so as to simulate a three-dimensional picture frame. Two-dimensional

is typically used for any inner borders, so as to simulate a mat board. In three-dimensional

embodiments, two shading colors are preferably provided, one which is lighter than the

10 border color and one which is darker than the border color. The shading colors are

typically used at the outer and inner edges of the three-dimensional border. The location

of the edges having the lighter shading color and the edges having the darker shading

color provide a visual perception of light striking the framed image from a specific

direction.

15   After 146 has been completed, all the frame attributes have been determined. The

generation of a data set for the framed image 24 from the data set for the unframed image

22 and the frame attributes is done by conventional means, the details of which are well

known to those skilled in the art.

Considering now in further detail the modifying 112 of the mapping relationship,

20 the user has the ability to modify or override the attributes of the frame 26 that is

automatically generated based on the image contents without user intervention, as has

- 18 -

already been described above. These modifications are preferably performed by changing

one or more of the relationships in Table I that determine the framing scheme parameters

(color scheme, intensity, texture, and dimensionality) for the particular predefined image

category associated with the image being framed. In some embodiments these

5   modifications will apply only to the image presently being framed, while in other

embodiments these modifications will also be applied to other images that fall into the

image category that is modified. Some embodiments also allow the user to specify the

number and width of the borders, the desired size of the framed image 26, and/or a scaled

size for the representation 22' of the unframed image. After the mapping relationship has

10   been modified, the determining 106 of frame attributes is performed again.

Returning now to the image processing apparatus 10 in order to consider the

image analyzer 20 in further detail, and with reference to FIGS. 1 and 2, the data set for

the unframed image may be supplied from image sources which include but are not limited

to a mass storage device 12a, a network source 12b, a digital camera 12c, an optical

15   scanner 12d, or the optical scanner module of a multifunction printer 12e. The image

analyzer 20 further includes a component identifier 28 which processes the data set as has

been previously described so as to identify one or more individual image components. The

analyzer 20 also includes a component characterizer 30 which receives the image

components from the component identifier 28 and determines at least one component

20   characteristic for certain ones of the individual image components; an image characterizer

34 which is communicatively coupled to the component characterizer 30 for determining

- 19 -

at least one image characteristic from the at least one component characteristic as has been previously described; and an image categorizer 36 which is communicatively coupled to the image characterizer 34 for automatically defining the at least one frame attribute from the at least one image characteristic, as has also been previously described in detail. The

5   image processing apparatus 10 also preferably includes a memory 44 accessible by the image categorizer 36, the image categorizer 36 automatically defining the at least one frame attribute in accordance with at least one framing scheme parameter stored in the memory 44. The preferred embodiment of the memory is preferably writeable, and the apparatus 10 preferably also has a user interface 38 communicatively coupled to the

10   memory 44 for modifying the at least one framing scheme parameter.

In the preferred embodiment, the image processing apparatus 10 includes a computing apparatus, and the image analyzer 10 and framed image generator 40 are implemented as computer programs in software, firmware, or a combination thereof. These programs are preferably stored intermittently or permanently in the memory 44. The

15   memory 44 may include both volatile and nonvolatile memory components. Volatile components are those that do not retain data values upon loss of power. Nonvolatile components are those that retain data upon a loss of power. Thus, the memory 44 may comprise, for example, random access memory (RAM), read-only memory (ROM), hard disk drives, floppy disks accessed via an associated floppy disk drive, compact disks

20   accessed via a compact disk drive, magnetic tapes accessed via an appropriate tape drive,

- 20 -

and/or other memory components, or a combination of any two or more of these memory components.

The apparatus 10 can send the data set it generates for the framed image to imaging devices that include but are not limited to a printer 14a, a display or monitor 14b,

5 a network destination 14c, a mass storage device 14d, or a multifunction printer 14e.

From the foregoing it will be appreciated that the image processing apparatus and method provided by the present invention represent a significant advance in the art. Although several specific embodiments of the invention have been described and illustrated, the invention is not limited to the specific methods, forms, or arrangements of

10 parts so described and illustrated. For example, while data set analysis has been discussed with reference to either image space or color space, these analyses are not necessarily exclusive; regions of interest may be identified in image space, and then color space analysis may be performed on only those regions. In addition, while particular sets of component characteristics, overall image characteristics, framing scheme parameters, and

15 frame attributes have been described, it is understood that alternative sets are also usable with the present invention. Consequently, the invention is limited only by the claims.